PROCEEDINGS

OF THE

AMERICAN PHILOSOPHICAL SOCIETY

HELD AT PHILADELPHIA

FOR PROMOTING USEFUL KNOWLEDGE

VOL. XLIX JANUARY–JUNE, 1910 NO. 194

PHOTOGRAPHIC OBSERVATIONS OF DANIEL'S COMET.

(PLATES I–XXV.)

BY E. E. BARNARD.

(*Read April 25, 1908.*)

It is such a long time since one has had the opportunity of seeing a large comet that the sight of this beautiful object suspended in the quiet summer morning skies with its slender graceful tail streaming upwards into the night, was something long to be remembered. It was a very impressive picture and those who were fortunate enough to see it at its best must have been struck with its quiet and majestic beauty. This was specially the case for a few mornings in the middle of August when the moon was absent, and as late as the first week in September when, though very low in the east and visible only for a few minutes before dawn killed it, the tail could be traced for a distance of fifteen degrees or more.

This comet was discovered by Mr. Zaccheus Daniel at Princeton, N. J., on 1907, June 9. Though it proved to be one of the brightest comets that have appeared in the past twenty-five years, it was in some respects a disappointing object—disappointing only, however, in the want of new phenomena. It was visible to the naked eye for two full months. At one time its tail attained a length of twenty-five degrees. Shortly after perihelion passage—when last seen in the

morning sky—the nucleus was as bright as a first magnitude star. Singularly enough, the comet developed its most interesting changes a month or more before perihelion passage. When near perihelion, which occurred September 3, there were few changes in its appearance from morning to morning. At that time there seemed to be a uniform unbroken flow of the tail-forming particles, so that what streams there were, were not individually prominent or striking.

In the second half of July separate streams of matter were frequent and formed a most interesting feature of the tail. These were specially beautiful on July 17 and 19. On the first of these dates the tail, where it joined the head, was made up of some five broad, diverging streams, which gave it a splendid and symmetrical appearance. This is really the handsomest photograph I have ever seen of a comet.

Comparatively few observatories obtained photographs of this comet, which was a great pity, for it was worthy of far more attention from a photographic standpoint than it received. Several, however, succeeded in getting results that are important. Excellent photographs were obtained by Mr. W. A. Cogshall at the Kirkwood Observatory at the State University, Bloomington, Indiana, with a small reflecting telescope made by himself. Though these, from the limitations of the reflector, do not show a great length of tail, they are specially beautiful and valuable for the structural details. A good series was also obtained at Greenwich. Dr. Max Wolf secured some specially valuable photographs with the 30-inch reflector, whose large scale showed the tail near the head, on several dates, to be made up of a great number of thin rays.

An excellent series of photographs of the comet was made by Mr. Duncan at the Lick Observatory. Though the time interval between these last and those of the Yerkes Observatory is roughly only two hours, there are decided changes shown in the tail when these pictures are compared with those made at the Yerkes Observatory. Unfortunately the changes in the comet are such that there are no definite markings that can be measured on the photographs to determine the motion of the tail-producing particles, with perhaps one exception—that of July 11. There are twelve dates that

are common to the Lick and the Yerkes plates. Several of the Yerkes photographs show very little on account of clouds and thick sky on the dates in question.

Another fine series of photographs of the comet was made by M. F. Quénisset of M. Flammarion's observatory at Juvisy, France. The interval of some six hours makes this series specially valuable for comparison with plates taken in this country. I am greatly indebted to M. Quénisset for enlarged prints from eleven of these pictures. Out of these, there are eight dates which were duplicated at the Yerkes Observatory. A comparison of these photographs is of extremely great interest, and though there is but little material from which to accurately determine the amount of motion, progressive outward displacement, especially in the streamers, is strongly shown. A study of these photographs clearly shows how uncertain it is to connect the details of any two dates. Of course a disturbance may extend over several days and the matter from it still be visible, but any particular detail would not probably live through from one date to another. In some of M. Quénisset's photographs the change has been so great that it is almost impossible to be sure of the same features six hours after. What is quite evident, however, in the comparison, is that the structure of the tail (the streamers) has a decided outward motion as a whole; at the same time there is a diffusion effect that constantly tends to destroy the details.

Some of these comparisons follow:

July 19, Juvisy Plate.—There is a principal narrow ray that separates into two rays some distance out. A dark space intervenes between it and a broad streamer south, whose north edge is very definite. There is a very decided change shown in the Yerkes photograph. Two new short rays have appeared on the south side. The north ray has become broad and diffused and irregular. The changes are so striking that one can hardly be sure of the same features, though there is a general resemblance.

August 11.—In the Juvisy picture there are four distinct rays. The two middle ones diverge from a point close to the head. These two are clean cut in the Yerkes plate. The south one has become

much brighter and more definite. Their junction has bodily moved outward for quite a distance. The north ray of the four has closed in on the one close south of it. A broad light region on the south edge of the northern of the two middle rays has drifted outwards and is less marked.

August 14.—There is one broad widening stream in the Juvisy photograph, with two lesser ones symmetrically placed on each side. In the Yerkes plate there is a general resemblance to the other; though the tail is made up of three broad streamers, they are much further out. It looks as if the three had drifted out and fused together more or less. The whole system of tails has bodily receded from the comet.

August 19.—In the Yerkes plate the head has become relatively smaller. The tail has spread out very greatly, especially on the south side. There is less structure than in the Juvisy plate.

August 20.—In the Juvisy plate a principal ray divides to the north and joins a dark space behind the head. In the Yerkes plate this ray and dark space have both moved outwards. The head and neck are also narrower.

On July 11 (which date we will treat specially) a bright condensation $1\frac{1}{4}°$ back from the head is strongly shown on both the Yerkes and Lick plates and can be seen on the Juvisy plate, but it is faint and cannot be located with very great accuracy on this last picture. A plate made at the Lick on July 10 seems to show this same object somewhat nearer to the comet or about $\frac{3}{4}$ as far out as on the eleventh. It is noticeable on all three photographs of July 11 that this condensation was receding from the comet, at the same time that it was following slowly towards the sun. From the appearance I am inclined to think that it is the same object which is visible on the plate of July 10. If so, then it must have left the comet on or about July 7. Between this condensation and the head of the comet on July 11 the tail is very faint but continuous. In reality this mass is the near end of a bright strip of the tail about 3° long. The object on the Lick plate of July 10 is joined to the head by a bright, strongly defined connection, of which the condensation is only an inconspicuous part. In the interval between July 10 and

11 the mass (if the same) had increased its distance from the head by about 20′. In the meantime it had drifted sunward 1° 10′—following in the direction of the comet's motion. It is probable that this was due to its original motion when a part of the comet, and that if its existence had been permanent enough, the motion would have become one of recession from the sun, but it rapidly dissipated before other photographs could be made of it.

With the aid of the BD charts I have taken off the following positions on the photographs of July 11:

	Position of the Head 1855.0.	Position of the Condensation 1855.0.
Juvisy,	$1^h\,48^m.05 + 8°\,12'$	$1^h\,44^m.0 + 7°\,54'$
Yerkes,	$1^h\,49^m.50 + 8°\,19'$	$1^h\,45^m.0 + 7°\,53'$
Lick,	$1^h\,50^m.05 + 8°\,18'$	$1^h\,45^m.0 + 7°\,54'$

The position angles of the mean axis of the tail on this date are:

Juvisy,	P. A.	251°.5
Yerkes,		251°.5
Lick,		251°.0

If one should take the brighter, long part of the tail, independent of the head, the axis of it would pass a little north of the head.

The following positions were taken off by the aid of the BD charts on the plates of July 19.

Juvisy.—Position of the head 1855.0 $2^h\,40^m.50 + 11°\,29'$. Position angle of the middle long, bright branch of the tail 249°.2. The main or central branch separates at 37′.7 back of the head. The south branch of the tail is 5° less in position angle than the middle one.

Yerkes.—Position of head 1855.0 $2^h\,42^m.67 + 11°\,33'$. Position angle of main branch of the tail (n. of 2) 253°.5. The south one was in P.A. 250°, but was irregularly curved.

Lick.—Position of head 1855.0 $2^h\,42^m.50 + 11°\,32'$. Position angle of main and largest branch 252°.9.

The following are the positions on August 11, derived from the charts.

Juvisy.—Position of head 1855.0 $6^h\,4^m.70 + 17°\,23'$. Position

angle of south ray 257°.0. Position angle of north ray 270°.0; not extreme north ray.

Yerkes.—Position of head 1855.0 $6^h\ 7^m.10 + 17°\ 23'$. Position angle of south ray 259°.0; assuming center of head as origin. Position angle of north ray 269°.0; assuming center of head as origin.

On a number of mornings I carefully examined the comet with the 40-inch telescope and its 4-inch finder. In the great telescope the view was not satisfactory because of the very small field — $5\frac{1}{2}'$ of arc. It showed the nucleus, however, and part of the head very well. The view in the finder was very much more satisfactory, but even this was a disappointment. The nucleus and head and part of the tail were very beautiful. The soft nebulous light of the comet with the bright yellowish star-like nucleus imbedded in the head made a very striking picture. But there were no details visible in either the head or the tail. The streamers which were shown on the photographs at about the same time could not be seen. Viewing the comet thus and then afterwards seeing the photograph of it, impressed one greatly with the value of photography in dealing with these objects. I think most of the phenomena of this comet would have passed away unknown had it not been for the photographic plate.

Notes on the Appearance of the Comet with the Naked Eye, with the 5-inch Guiding Telescope and with the 40-inch and its 4-inch Finder.

July 15.—The comet was visible to the naked eye as a hazy star of the fourth magnitude. It was decidedly brighter than the Andromeda nebula, but much smaller. It was ½ magnitude brighter than the star 3° east of it, BD + 9° 316 (1855.0 $2^h\ 17^m\ 3^s.0 + 9°\ 57'.9\ 5^m.7$). While guiding it seemed to fade for short intervals—perhaps this was due to thin patches of clouds, though I could not see any clouds.

July 17.—Bright to naked eye. It was $3\frac{1}{2}$ magnitude. Very much like a considerable hazy star. Could faintly see a very slender tail for 5°± which passed several faint stars 4° from the head. The comet was ½ magnitude or more brighter than the fourth mag-

nitude star, BD $+7°$ 388 (1855.0 2^h 20^m $27^s.7$ $+7°$ 48′.4 $4^m.5$), 4°± south of it. It was brighter than any of the stars near.

July 18.—To the naked eye, when best seen—visible only through gaps in clouds—the head was third magnitude. It seemed to be brighter than on the seventeenth.

July 19.—I am sure there were frequent fluctuations of the comet's light to the extent of about one magnitude. To the naked eye the comet was 3½ magnitude. At best it was ½ magnitude brighter than the naked eye star, BD $+9°$ 359 (1855.0 2^h 37^m $6^s.0$ $+9°$ 29′.9 $4^m.0$), 3° s.w. of it. Could see faint suggestions of a tail. Good sky.

July 28.—15^h 45^m. The head was conspicuous, like a hazy star, notwithstanding a gibbous moon. In the finder of the 40-inch I could trace the tail faintly across the field (2°). There was a bright stellar nucleus of about the sixth magnitude. In the 40-inch the nucleus was very bright, but not stellar. The head filled the field of view (5½′ power 460). There seemed to be a shadow effect behind the nucleus—away from the sun.

July 31.—In spite of the presence of a half moon the comet was conspicuous, like a hazy star, 2° west of Aldebaran. I could see it with the naked eye as late as 16^h 3^m.

August 1.—The comet was conspicuous, like a bright hazy star. It was the same brightness as δ^1 or δ^2 Tauri. Could not be certain of any tail. In the guiding telescope the nucleus was not so distinct as it was on July 31.

August 3.—It was conspicuous like a small 3 or 3½ magnitude star. There were faint suggestions of a tail to the naked eye. It was not decidedly brighter [than on the first]. There was, of course, less moonlight than on the other morning. In the 5-inch the nucleus was not definite—only a central condensation. There seemed to be fluctuations in its light with the 5-inch and I think they were verified with the naked eye.

August 5.—To the naked eye the head of the comet was equal to ζ Tauri. The tail was about 15° in length and stretched out to within a degree or two of Aldebaran. At times I thought I could see it as far as Aldebaran. It would have passed south of that

star and was fairly distinct. The comet was a conspicuous object to the naked eye.

August 6.—With the naked eye the head was as bright as ζ Tauri. Could trace the tail, which was conspicuous but not bright, as far as Aldebaran, where it passed south of that star; it was neither slender nor broad—and seemed to be straight. With the 40-inch the nucleus was not stellar but was bright and yellowish. It was blurred or ill defined in the direction of the sun—apparently spread out—while on the opposite side (away from the sun) it was quite definite wtih a darker space in the nebulosity. The head was much larger than the field of view. In the finder, the tail stretched away across the field. There was a sixth magnitude yellowish star in it, about $\frac{1}{2}^\circ$ back from the head. There was no detail or structure in the comet as seen in the 4-inch finder. The nucleus was about the fifth magnitude and almost stellar. The tail was very slender. The edges were soft and roundish—like a cylindrical or conical body. It was very beautiful in the finder.

August 8.—To the naked eye the tail seemed to be almost the same as on the sixth and was not sensibly longer, but the head was brighter. The comet was $\frac{1}{2}$ magnitude brighter than ζ Tauri and about equal to θ Aurigæ. The sky was good. With the 40-inch the measured diameter of the nucleus at $16^h\ 7^m$ was $2''.49$. This gives a diameter of 2,580 miles. It was slightly yellow. There was a sharp outline several minutes long nearly straight, which passed the preceding edge of the nucleus and which bounded a much denser nebulosity following, in which the nucleus was immersed. The position angle of this definitely bounded nebulosity was $160^\circ.6$ (1) at $16^h\ 8^m$. In the finder the nucleus was stellar and bright. The comet was still faintly visible with the naked eye at $16^h\ 19^m$, but at the limit of vision on the dawn-lit sky.

August 9.—Sky not very transparent. The tail was not so conspicuous as on the eighth; the head seemed brighter, however. It could be faintly traced to a distance as great as that from ζ Tauri to Aldebaran (16°). The head was somewhat less bright than λ Orionis.

August 10.—Sky very good. To the naked eye the comet was

bright for some 3° or 4° back from the head. The nucleus was visible to the eye as a star of about the third magnitude. The head was midway in brightness between that of ζ Tauri and λ Orionis. The tail could be traced faintly for at least 15°. It was pretty faint but when looked at with averted vision it could be seen fairly well for a distance equal to that from ζ Tauri to Aldebaran. The end of the tail just reached to BD + 15° 732 (1855.0 4^h 56^m $18^s.0$ + 15°12′.3).

August 11.—The tail, with the naked eye, could be traced to BD + 15° 732. The south edge would pass through that star. It was 1° or 1½° wide at that point. Though faint, it could be seen quite well. It was straight and somewhat narrow. The nucleus was conspicuous as a star-like body in the head. The head itself was narrow. The tail was bright for 2° or more and then it faded out rapidly towards the end. The head was as bright as η Geminorum. In the 40-inch the nucleus was ill defined, and blurred into the brightness following. It was distinct at the preceding edge.

August 12.—Sky first-class. With the naked eye the nucleus was bright and stellar. It was about as bright as η Geminorum. The tail was perhaps a little brighter than before but rather feeble except near the head. I could trace it faintly nearly to BD + 15° 732. The head was as conspicuous as γ Geminorum, near and to the east, but the nucleus was much less bright than that star.

August 13.—The sky was very thick, and part of the time at first the comet was behind clouds.

August 14.—Clouds at first covered the comet. It then came out and was conspicuous about 2° east of γ Geminorum. When the comet and star came out of the clouds they were very much alike, but as they rose higher the stellar condition of the nucleus was much inferior to the star—say 1 magnitude less bright. The tail was straight and rather slender. For 5° back of the head it was pretty bright, then for the rest of its length it was faint. It could, however, be readily traced to 126 Tauri (Proctor's chart).

August 19.—It was bright to the eye—perhaps brighter than before. The tail could not be traced far—perhaps nearly to γ Geminorum. Sky very poor.

August 20.—With the naked eye the comet was a very graceful and beautiful object. The tail could be faintly traced to about γ Geminorum. The nucleus was star-like and bright.

August 21.—After the nearly full moon set, the sky was still affected by moonlight when dawn began. At $15^h\ 30^m$ or $15^h\ 40^m$ the comet was bright. The nucleus was bright to the eye and was perhaps of $2\frac{1}{2}$ magnitude. The head was not as conspicuous as γ Geminorum—but not much inferior to it.

August 22.—Full moon. The head and nucleus of the comet were conspicuous in spite of the moonlight. The nucleus was about $2\frac{1}{2}$ magnitude. The tail was noticeable or conspicuous for 3° or 4°. In looking in its direction one would have been impressed with its distinctness.

August 24.—Nearly full moon. Sky clear. The comet was conspicuous. Even in the bright moonlight I could see the tail for 4° or 5°.

August 25.—In clouds and haze.

August 31.—Sky good and clear. Crescent moon. The comet was fairly noticeable to the naked eye when its place was known. Could feebly trace the tail for 4° or 5°.

September 2.—It was conspicuous to the eye with a tail 4° or 5° long even in the strong moonlight. The nucleus was about 2 or $2\frac{1}{2}$ magnitude.

September 5.—The comet was very low but the head was bright. The tail, though not bright, could be traced for 14° as drawn on a star chart. It was long and straight and gradually faded out to the end. The sky was fairly good, but as dawn came up some masses of haze were visible in the east. It was estimated that, to the eye, the head and nucleus were about third magnitude. Very slender crescent moon near horizon.

September 8.—To the naked eye the nucleus was as bright as a first magnitude star. The tail could be traced 5° or 6° but partly hidden by clouds.

September 11.—The comet was very low. The nucleus was fairly distinct to the naked eye, but there was only a suggestion of a tail. It had faded very much since the eighth [due to its low position?]. Sky lit with dawn.

September 12.—I could not see it with the naked eye though I tried hard. Not bright in guiding telescope. Sky not pure. Strong dawn.

The photographs taken here of this comet were made with the 10-inch, the 6.2-inch and the 3.4-inch portrait lenses of the Bruce telescope of the Yerkes Observatory. The plates used were Seed 27 Gilt Edge. They were backed with a dark red paste made of burnt sienna and caramels.

Much trouble was experienced from cloudy weather and bad skies. Every opportunity was taken advantage of, however, to secure photographs of the comet. I am greatly obliged to my friend Dr. S. A. Mitchell, who guided for me on several mornings that work with the large telescope would otherwise have prevented photographs being secured. On a few mornings Dr. Mitchell attached his small camera with a Goerz double anistigmat lens of $1\frac{1}{4}$-inch aperture and 6-inch focus $\therefore a/f = \frac{1}{4.8}$, on to the Bruce mounting, and secured some negatives which showed a greater length of tail than was possible with the other lenses.

Following is a list of the photographs made with the Bruce telescope:

In the column marked "Lenses," *a* is the 10-inch Brashear doublet, *b* the 6-inch, *c* the 3.4-inch and *d* the $1\frac{1}{4}$-inch Goerz lens.

In conclusion it would seem that we have to deal with several different kinds of physical phenomena in the study of comets. These are doubtless closely related and are probably the same phenomena acting under different conditions.

There is the regular production of the tail through the repellent action of the sun's light. The tail forming particles in this case will be very small. They may go out from the comet as a broad stream or they may produce several streams more or less narrow. The direction of these various rays are dependent, to some extent, on an exciting and directing force in the comet itself, but the general direction will be more or less influenced by light pressure. These streams, or rays, will be more or less uniformly straight or curved—almost always straight or nearly so. They may be broken or abruptly deflected but this will be due to some influence encountered

in their progressive motion in the general direction of the comet's flight. Such streams will more nearly represent the true emissive velocity of the particles. I have shown in the *Astrophysical Journal*, Vol. XVIII., p. 214, in the case of Borrelley's comet, that the tail of a comet actually moves forward bodily as a whole both outward from the sun and progressively in the direction of the comet's mo-

List of Photographs of Daniel's Comet Made with the Bruce Telescope.

Approximate Position 1855.0.

		α	δ	Cent. Stan. Time.	Duration of Exposure.	Lenses.	
		h. m.	° ′	h. m.	h. m.		
June	20	0 18	+ 1 20	14 23	0 45	a b	
July	3	1 8	+ 5 15	14 6	1 2	a b	
	11	1 49.5	+ 8 20	13 58	2 12	a b c	
	13	2 1.5	+ 9 6	14 7	1 55	a b c	
	15	2 14	+10 0	13 52	2 20	a b c	
	17	2 27.5	+10 40	13 59	2 10	a c	
	17	2 27.5	+10 40	14 27	1 14	b	
	18	2 35	+11 10	14 7	1 50	a b c	
	19	2 42	+11 32	13 54	2 18	a b c	
	20	2 50±	+12 0±			a b c	
	29	4 6	+15 30	14 41	1 40	a b c	
	31	4 24	+16 0	15 2	1 17	a b c	
Aug.	1	4 33	+16 9	14 46	1 45	a b c	
	3	4 53	+16 40	14 53	1 40	a b c	
	5	5 11	+17 5	15 8	1 6	a b c	
	6	5 21	+17 10	15 3	1 21	a b c	
	8	5 39	+17 22	15 30	0 33	a b c	
	9	5 50	+17 20	15 1	1 32	a b c	
	10	5 58	+17 25	14 57	1 43	a b c	
	11	6 7	+17 25	14 59	1 42	a b c d	
	12	6 16	+17 25	15 7	1 43	a b c d	
	13	6 25	+17 20	15 8	1 11	a b c d	
	14	6 34	+17 20	15 11	1 20	a b c d	
	17	7 0	+16 55	15 10	1 30	a b c d	
	19	7 16	+16 30	15 40	0 40	a b c d	
	20	7 24	+16 30	15 27	1 5	a b c d	
	21	7 33	+16 30	15 36	0 50	a b d	
	22	7 39	+16 5	15 40	0 44	a b c d	
	23	7 47	+16 0	15 45	0 40	a b c d	
	24	7 54	+15 40	15 48	0 34	a b c d	
	25			15 23	0 5	a b	
	29			15 45±		a b c d	Few min. only, clouds
	30			15 55		a b c d	" " " "
	31	8 45	+14 20	15 59	0 39	a b c d	
Sept.	2	8 58	+13 10	15 51	0 18	a b c	
	5	9 18	+12 30±	16 0	0 37	a b c	
	8	9 34	+11 20	16 17±	0 5±	a b	
	11			16 19	0 24	a b c	
	12			16 25	0 20	a b c	

tion, and that some of the particles must move outward from the sun very much faster than others of the same stream. This was shown in the formation of the new tail of the above-named comet on July 24. In the tail on that date the later photographs showed that the end of the new tail was increasing its distance from the head much faster than the end of the receding disconnected tail. But in this case the conditions were different; the supply of matter forming the outgoing stream had suddenly been stopped and the stream itself continued to move out bodily into space until it was dissipated. The apparent velocity was then the velocity of the stream of particles. In the case of Daniel's comet a denser mass of particles differing from the general streams that formed the tail was separated from the main body. This would naturally leave the comet slowly and continue to partake of the original motion. Still another case was that of Brook's comet of 1889 (comet V., 1889) where the masses thrown off were so dense that they traveled with the parent comet for months as individual companions before finally disappearing.[1] And yet another case, that of Biela's comet which separated into two masses that remained individually distinct for some years and then entirely disintegrated. The motion of a dense mass thrown off from a comet would not therefore be a criterion for the determination of the velocity in general of the particles of the tail of such a comet.

The plate of September 8 is introduced, not from any scientific value it may have, but from an artistic standpoint and from its unique character. So far as I know this is the only comet, or star photograph, on which clouds are actually shown. The exposure was very short, for the comet was visible for only a few minutes in a break. The clouds stand out black and distinct on the dawn-lit sky. To the eye it was a beautiful and striking scene—the comet in pale but clear relief on the dawn-whitening sky, the dark clouds, through a break in which the comet shone, and the solemn stillness of the morning, made it a picture not soon to be forgotten. The photograph rather faithfully records the appearance of the comet and clouds and dawn-lit sky, but the reproduction cannot do justice to the

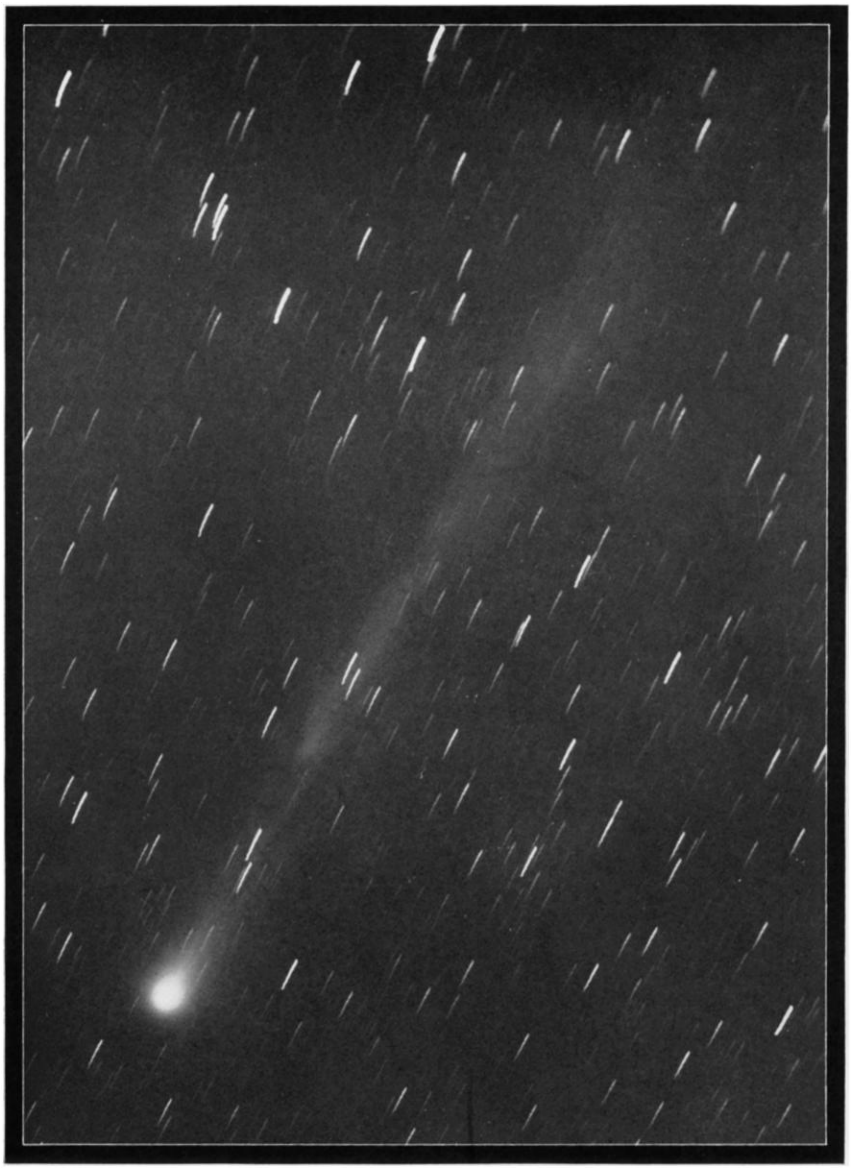
[1] See *Astronomische Nachrichten,* nos. 2914, 2919, 2988 and 2998.

reality. Quite a number of stars appear upon the original which heighten the artistic effect, but they have disappeared in the reproduction.

The great delay in the appearance of this paper has been due entirely to the difficulty of getting good half-tone reproductions. (E. E. B.)

PLATE I

West



Comet 1907 *d* (Daniel) on July 11, 1907, at $13^h\ 58^m$ C.S.T.
Exposure $2^h\ 12^m$. Scale: 1 inch = 46′
10-inch Bruce Portrait Lens. Yerkes Observatory.

PLATE II

West

Comet 1907 *d* (Daniel) on July 15, 1907, at $13^h\ 52^m$ C.S.T.
Exposure $2^h\ 20^m$. Scale: 1 inch = $32'$
10-inch Bruce Portrait Lens. Yerkes Observatory.

PLATE III

West

Comet 1907 *d* (Daniel) on July 17, 1907, at $13^h\ 59^m$ C.S.T.
Exposure $2^h\ 10^m$. Scale: 1 inch = 50′
10-inch Bruce Portrait Lens. Yerkes Observatory.

PLATE IV

West

Comet 1907 *d* (Daniel) on July 19, 1907, at 13^h 54^m C.S.T.
Exposure 2^h 18^m. Scale: 1 inch = 49′
10-inch Bruce Portrait Lens. Yerkes Observatory.

PLATE V

West

Comet 1907 *d* (Daniel) on July 29, 1907, at $14^h\ 41^m$ C.S.T.
Exposure $1^h\ 40^m$. Scale: 1 inch = 44′
10-inch Bruce Portrait Lens. Yerkes Observatory.

PLATE VI

West

Comet 1907 *d* (Daniel) on August 3, 1907, at $14^h\ 53^m$ C.S.T.
Exposure $1^h\ 40^m$. Scale: 1 inch = 49′
10-inch Bruce Portrait Lens. Yerkes Observatory.

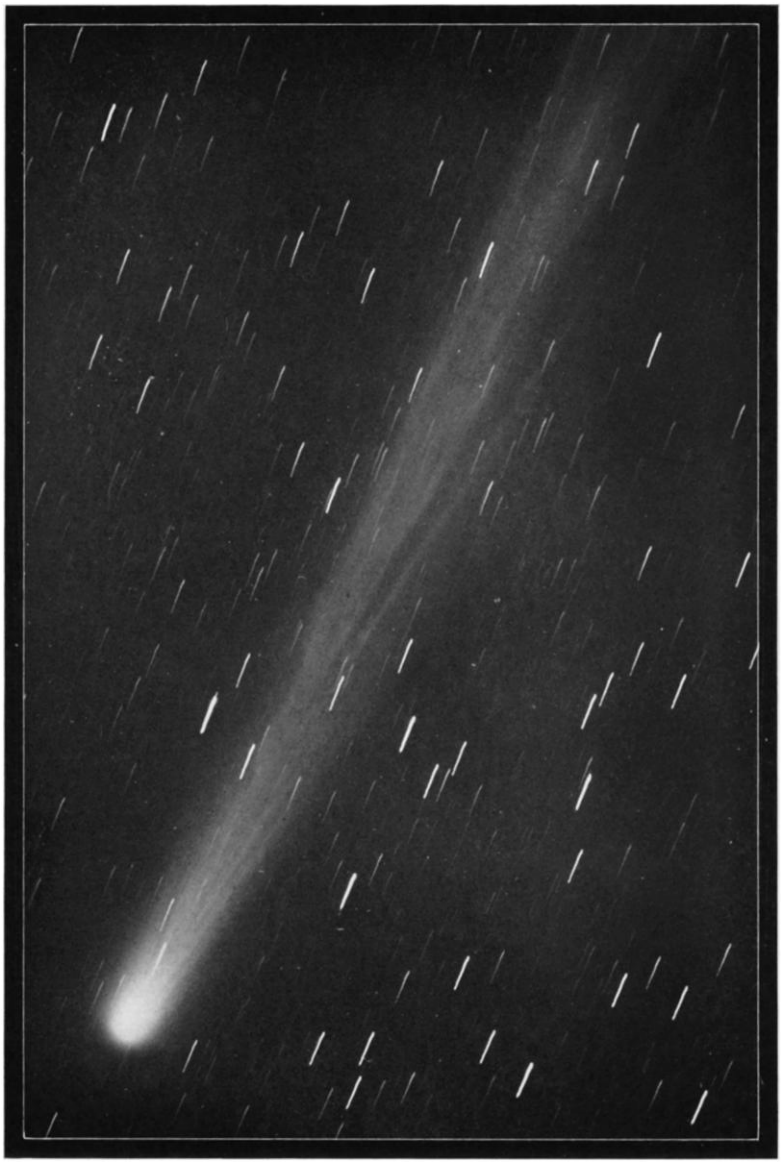
PLATE VII

West

Comet 1907 *d* (Daniel) on August 5, 1907, at $15^h\ 8^m$ C.S.T.
Exposure $1^h\ 6^m$. Scale: 1 inch = 42′
10-inch Bruce Portrait Lens. Yerkes Observatory.

PLATE VIII

West



Comet 1907 *d* (Daniel) on August 6, 1907, at 15^h 3^m C.S.T.
Exposure 1^h 21^m. Scale: 1 inch = 39′
10-inch Bruce Portrait Lens. Yerkes Observatory.

PLATE IX

West

Comet 1907 *d* (Daniel) on August 8, 1907, at 15^h 30^m C.S.T.
Exposure 0^h 33^m. Scale: 1 inch = 44′
10-inch Bruce Portrait Lens. Yerkes Observatory.

PLATE X

Comet 1907 *d* (Daniel) on August 9, 1907, at 15^h 1^m C.S.T.
Exposure 1^h 32^m. Scale: 1 inch = 50′
10-inch Bruce Portrait Lens. Yerkes Observatory.

PLATE XI

West

Comet 1907 *d* (Daniel) on August 10, 1907, at 14^h 57^m C.S.T.
Exposure 1^h 43^m. Scale: 1 inch = 42′
10-inch Bruce Portrait Lens. Yerkes Observatory.

PLATE XII

Comet 1907 *d* (Daniel) on August 11, 1907, at 14^h 59^m C.S.T.
Exposure 1^h 42^m. Scale: 1 inch = 44′
10-inch Bruce Portrait Lens. Yerkes Observatory.

PLATE XIII

West

Comet 1907 *d* (Daniel) on August 11, 1907, at 14^h 59^m C.S.T.
Exposure 1^h 42^m. Scale: 1 inch = 129′
3.4-inch Bruce Portrait Lens. Yerkes Observatory.

PLATE XIV

West

Comet 1907 *d* (Daniel) on August 12, 1907, at $15^h\ 7^m$ C.S.T.
Exposure $1^h\ 43^m$. Scale: 1 inch = 51′
10-inch Bruce Portrait Lens. Yerkes Observatory.

PLATE XV

Comet 1907 *d* (Daniel) on August 13, 1907, at $15^h\ 8^m$ C.S.T.
Exposure $1^h\ 11^m$. Scale: 1 inch = 41′
10-inch Bruce Portrait Lens. Yerkes Observatory.

PLATE XVI

West

Comet 1907 *d* (Daniel) on August 14, 1907, at $15^h\ 11^m$ C.S.T.
Exposure $1^h\ 20^m$. Scale: 1 inch = 53′
10-inch Bruce Portrait Lens. Yerkes Observatory.

PLATE XVII

West

Comet 1907 *d* (Daniel) on August 14, 1907, at 15^h 11^m C.S.T.
Exposure 1^h 20^m. Scale: 1 inch = 141′
3.4-inch Bruce Portrait Lens. Yerkes Observatory.

PLATE XVIII

West

Comet 1907 *d* (Daniel) on August 17, 1907, at 15^h 10^m C.S.T.
Exposure 1^h 30^m. Scale: 1 inch = 49′
10-inch Bruce Portrait Lens. Yerkes Observatory.

PLATE XIX

West

Comet 1907 *d* (Daniel) on August 19, 1907, at 15^h 40^m C.S.T.
Exposure 0^h 40^m. Scale: 1 inch = 36′
10-inch Bruce Portrait Lens. Yerkes Observatory.

PLATE XX

West

Comet 1907 *d* (Daniel) on August 20, 1907, at 15^h 27^m C.S.T.
Exposure 1^h 5^m. Scale: 1 inch = 53′
10-inch Bruce Portrait Lens. Yerkes Observatory.

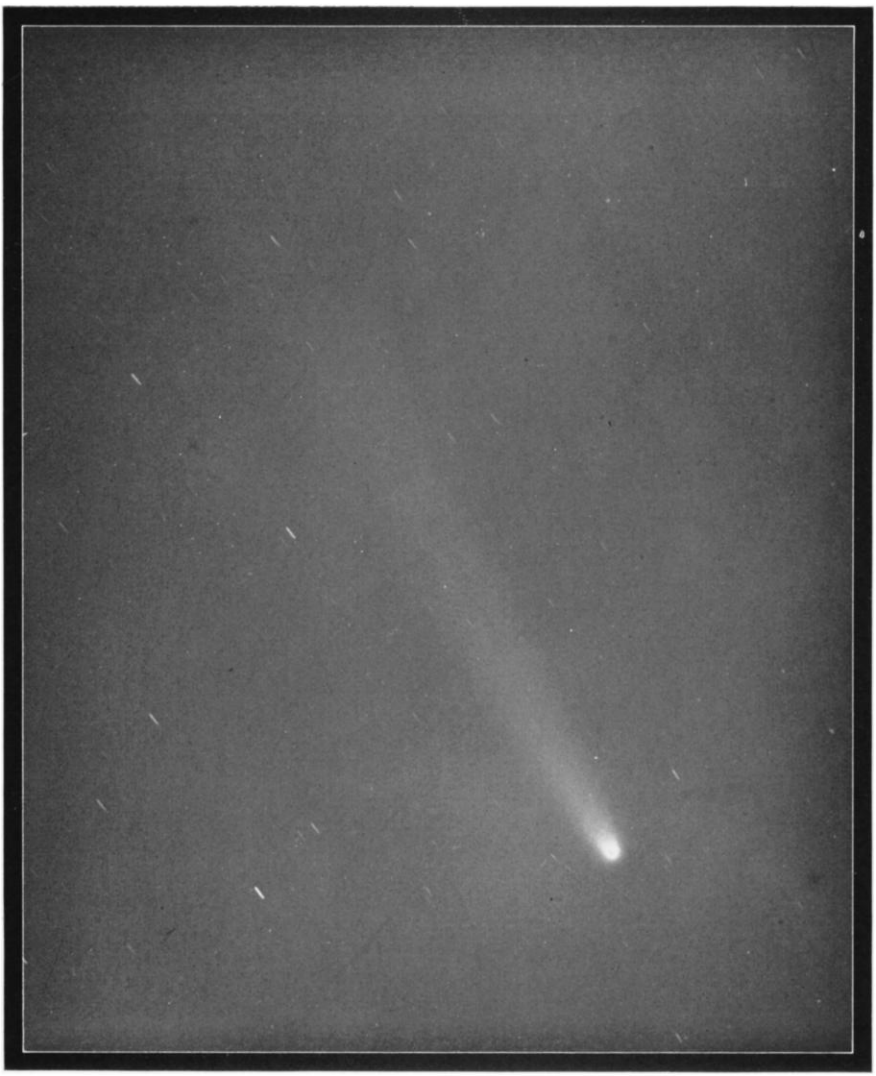
PLATE XXI

West

Comet 1907 *d* (Daniel) on August 21, 1907, at 15^h 36^m C.S.T.
Exposure 0^h 50^m. Scale: 1 inch = 56′
10-inch Bruce Portrait Lens. Yerkes Observatory.

PLATE XXII

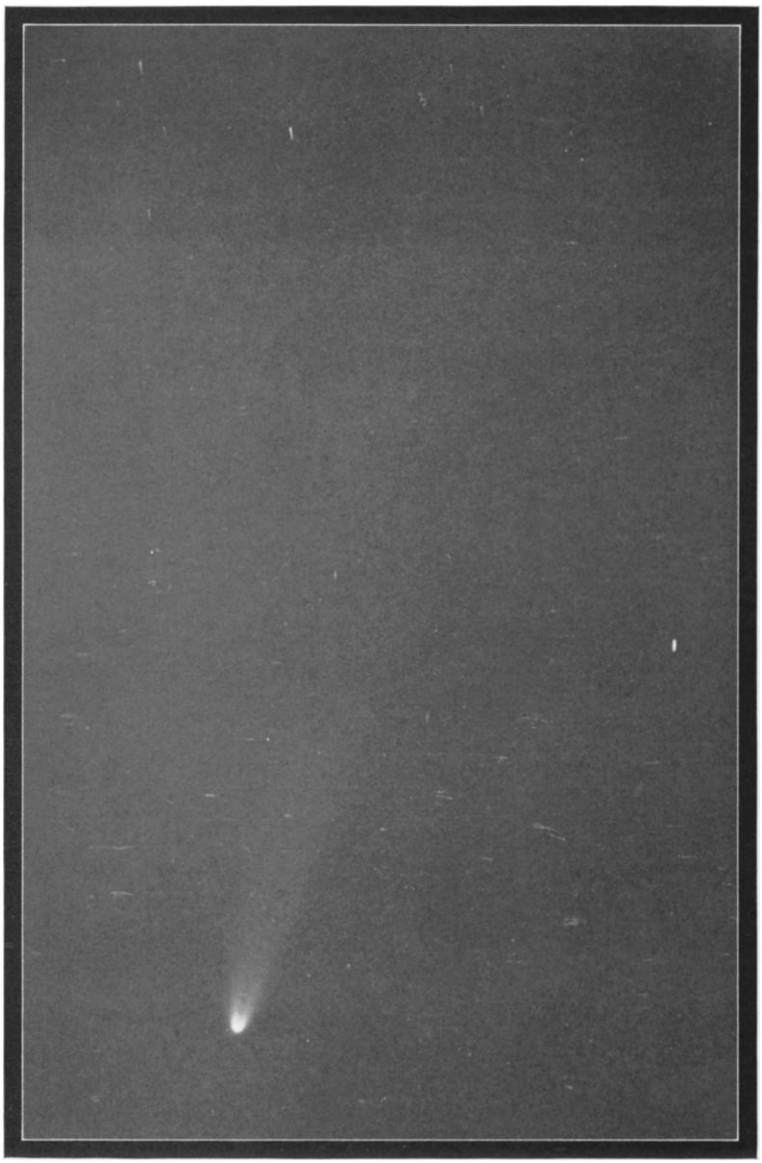
West



Comet 1907 *d* (Daniel) on August 24, 1907, at $15^h\ 48^m$ C.S.T.
Exposure $0^h\ 34^m$. Scale: 1 inch = 39′
10-inch Bruce Portrait Lens. Yerkes Observatory.

PLATE XXIII

West



Comet 1907 *d* (Daniel) on September 2, 1907, at $15^h\ 51^m$ C.S.T.
Exposure $0^h\ 18^m$. Scale: 1 inch = 39′
10-inch Bruce Portrait Lens. Yerkes Observatory.

PLATE XXIV

West

Comet 1907 *d* (Daniel) on September 5, 1907, at 16^h 0^m C.S.T.
Exposure 0^h 37^m. Scale: 1 inch = 38′
10-inch Bruce Portrait Lens. Yerkes Observatory.

PLATE XXV

West

Comet 1907 *d* (Daniel) on September 8, 1907, at 16^h 17^m C.S.T.
Exposure 0^h 5^m. Scale: 1 inch = 90′
6¼-inch Bruce Portrait Lens. Yerkes Observatory.